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Regional Rainfall Characteristics of Hong Kong Over the Past 50 Years

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Abstract

The rainfall data collected from the Hong Kong Observatory's rainfall monitoring network over the latest 50 years (1956 - 2005) were used to study the regional rainfall characteristics of Hong Kong. The study reveals that, although not statistically significant, the rainfall over different regions of Hong Kong was generally on a rising trend ranging from 34 mm to 103 mm per decade. The rate was higher over urban areas than the New Territories, offshore islands and high grounds.

Spectral analysis using the Multitaper Method reveals that the rainfall in different regions of Hong Kong had a periodic cycle of about 4 years, coinciding with that of El-Niño Southern Oscillation (ENSO). Rainfall was generally higher in El Niño onset years and the years immediately following El Niño onsets.

Urbanization is one of the possible causes for the rainfall's increasing trend and the regional variation in Hong Kong. The urban heat island effect enhances convective activity and the increase in concentration of suspended particulates from urban activities also favours the formation and development of rain-bearing clouds.

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1. Introduction

Hong Kong has a complex terrain and is surrounded by sea on three sides. Over the last few decades, there were large differences between the development of urban and rural areas in Hong Kong. This report presents the regional rainfall characteristics in Hong Kong over the past 50 years and discussed the influence of urbanization on the regional rainfall trends.

2. Data

The rainfall monitoring network of Hong Kong consists of manned and automatic raingauge stations. There were only a few manned raingauge stations in Hong Kong until 1952, when about 30 stations were set up. The number then increased steadily to about 120 in 1980's. Starting from 1983, automatic raingauges began to be deployed, with some replacing manned stations. The rainfall monitoring network in Hong Kong now comprised mainly of automatic raingauges.

For all these raingauge stations, there are in total 23 locations with rainfall records spanning 40 years, and 17 locations with rainfall records spanning 50 years. Some of them are manned raingauges which have been operating since 1950s while at some locations, the manned raingauges had been replaced by the automatic raingauges in 1980s and 1990s.

The monthly and annual rainfall data recorded at these raingauge stations from 1956 to 2005 were used in this study. To reduce the impact of missing data on the analysis, missing and incomplete monthly data of a particular station was either filled in by the average of nearby stations or adjusted using the statistical correlation (when correlation coefficient is greater than 0.9) between the rainfall of the station and nearby stations [1-3].

3. Methodology

3.1 Grouping of rainfall stations

Amongst the 23 stations mentioned in Section 2, 15 of them with longer data period, more complete data and suitable spatial distribution were used to analyze the regional rainfall characteristics. These stations were stratified into five groups. Each group has 3 stations and represents a region in Hong Kong, namely:

(i) Urban;
(ii) High Ground;
(iii) New Territories East;
(iv) New Territories West; and
(v) Offshore

Details of grouping and locations of these 15 stations were summarized in Table 1 and Figure 1 respectively.

3.2 Trend analysis

Rainfall trend analysis was made using linear regression and t-test [4-5]. Linear regression lines were fitted to the parameters by least squares. The long-term trend was then taken as the slope of the fitted straight line. Two tailed t-test was applied to test the statistical significance of the trends at 5% significance level. The test statistics t used for statistical testing is:

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

where r is the correlation coefficient and follows a t-distribution with n-2 degrees of freedom.

3.3 Spectral analysis

The Multitaper Method (MTM) is used to carry out a spectral analysis of the annual rainfall trend for each of the five regions. Compared with Fourier and other traditional methods of spectral analysis, the spectral estimates given by MTM have lower variance and higher resolution [6]. The spectral peaks obtained by MTM are tested for statistical significance against the white-noise spectrum.

4. Results and discussion

4.1 Trends

The long-term trend of the annual rainfall in each of the five regions of Hong Kong over the latest 50 years (1956 - 2005) is listed in Table 2. It can be seen that the annual rainfall over all the five regions was all on a rising trend, ranging from 34 mm per decade in the New Territories East to 103 mm per decade in the Urban area. On average, the rainfall of all the five regions rose at a rate of 65 mm per decade, comparable with 20 – 60 mm per decade for South China [7]. None of the rising trends in all five regions is statistically significant at 5% level. This may be due to the large year to year rainfall variation.

As seen from Table 2, the rate of rainfall increase was higher in urban areas and lower in the New Territories and offshore islands. The difference in annual rainfall between the Urban and Offshore (the latter representing an undisturbed region) was increasing at 63 mm per decade, statistically significant at 5% level (Figure 2), whereas the difference in annual rainfall between each of the other regions (New Territories East, New Territories West and High Ground) and Offshore was lower and not statistically significant at the 5% level (Table 3). The regional variation was possibly due to the effect of urbanization which will be discussed in Section 4.3.

4.2 Variability

Figure 3 shows the result of spectral analysis by MTM on the average rainfall of all the five regions. A prominent peak at about 4 years exceeding the 95% confidence limit of white noise spectrum is observed. A prominent peak at about 4 years can also be found for each of the five regions of Urban, New Territories East, New Territories West, Offshore and High Ground. This

4-year period coincided with the period of El Niño Southern Oscillation (ENSO). For each El Niño onset year and the year immediately following the El Niño onset year, the average annual rainfall for all five regions is found to be generally higher than the 1961-1990 normal of 2214 mm (Figure 4), consistent with the findings by Chang and Yeung in 2003 [8].

4.3 Effect of urban development

The rapid urban development in Hong Kong in the past few decades might have brought about the rising rainfall trends discussed in Section 4.1. A number of recent studies has suggested that the "urban heat island" effect can induce more precipitation in the urban areas. This phenomenon is also referred as "urban rain island" effect in some literatures [9-13].

Urban development and deforestation replace natural land surfaces by buildings and artificial surfaces in a city. Since such surfaces are more capable of storing heat, an urban heat island may develop and cause the city to become warmer than its surroundings. In Hong Kong, the urban heat island effect was observed [15-16], which might have increased cloudiness and precipitation as thermal circulation was created in the surrounding region [13]. Heavy rain associated with pressure troughs or unstable southwest monsoon flow might also have been enhanced. Such an effect has been reported in other major cities in China like Shanghai, Beijing, etc [9]. Increased roughness over a city can also augment precipitation [11]. A recent case study in Shanghai showed that rain-producing systems such as stationary fronts often lingered longer over the urban area and enhanced the rain there compared with the rural area [13]. Moreover, the increase in the concentration of suspended particulates due to urban activities and hence condensation nuclei, might have helped the formation and development of rain-bearing clouds [16].

5. Conclusion

The regional rainfall characteristics in Hong Kong were studied using the rainfall data collected by the Hong Kong Observatory's rainfall monitoring network from 1956 to 2005. In these 50 years, the rainfall over different regions in Hong Kong showed a rising trend ranging from 34 mm to 103 mm per decade. The rising rate was the largest over urban areas. The urban heat island effect associated with the rapid urban development in the last few decades in Hong Kong is one of the possible causes accounting for the rising rainfall trend and its regional variation.

Spectral analysis also reveals that the rainfall in different regions of Hong Kong all exhibited a periodic cycle of about 4 years, tying in with the period of El-Niño Southern Oscillation.

References

1. Wiesner C.J., 1970, “*Hydrometeorology*”, Chapman and Hall Ltd, London.

2. Kwan, W.K. and B.Y. Lee, 1984, 30-year Mean Rainfall in Hong Kong 1953-1982, *Hong Kong Observatory Technical Note* No. **70**.

3. Ng, M.C. and K. P. Wong, 1996, 30-year Mean Rainfall in Hong Kong 1961-1990, *Hong Kong Observatory Technical Note* No. **88**

4. Easterling, D.R., B. Horton, P.D. Jones, T.C. Peterson, T.R. Karl, D.E. Parker, M.J. Salinger, V. Razuvayev, N. Plummer, P. Jamason, C.K. Folland, 1997, “Maximum and Minimum Temperature Trends for the Globe”, *Science*, **277**, 364-367.

5 Karl, T.R., P.D. Jones, R.W. Knight, G. Kukla, N. Plummer, V. Razuvayer, K.P. Gallo, J. Lindseay, R.J. Charlson and T.C. Peterson, 1993, “A New Perspective on recent Global Warming: Asymmetric Trends of Daily Maximum and Minimum Temperature”, *Bull. Am. Meteorol. Soc.*, **74**, 1007-1023.

6 Ghil, M., M.R. Allen, M.D. Dettinger, K. Ide, D. Kondrashov, M.E. Mann, A.W. Robertson, A. Saunders, Y. Tian, F. Varadi and P. Yiou, 2002, “Advanced spectrum methods for climatic time series”, *Rev. Geophys.*, **40**, 1-1-1-41.

7. Qin, D., Y. Ding, J. Zhang, Y. Xu and Y. Song, 2003, “*Evolution of Climate System and its Forecast*”, Meteorological Press, Beijing, 137pp (In Chinese).

8. Chang, W.L. and K.H. Yeung, 2003, “Seasonal Forecasting for Hong Kong – A Pilot Study”, *Hong Kong Observatory Technical Note* No. **104**.

9. 秦大河主編，李愛貞、劉厚鳳、張桂芹編著，2003，“氣候系統變化與人類活動”，氣象出版社，北京。

10. 黃增明、梁建茵、吳艷標、萬齊林編著，1994，“廣州城市氣候”，氣象出版社，北京。

11. Shepherd J.M., H. Pierce, A.J. Negri, 2002, “Rainfall Modification by Major Urban Areas: Observations from Spaceborne Rain Radar on the TRMM Satellite”, *J. Appl. Meteor.*, **41**: 689-701.

12. Dixon, P.G. and T.L. Mote, 2003, “Patterns and Causes of Atlanta’s Urban Heat Island – Initiated Precipitation”, *J. Appl. Meteor.*, **42**: 1273-1284.

13. Chow S.D., 1986, “Some aspects of the urban climate of Shanghai”, Proceedings of the technical conference organized by the World Meteorological Organization and co-sponsored by the World Health Organization, Mexico D.F., 26-30 November 1984, 87-109.

14. Sun, H.W. and N.C. Evans, 2002, “Comparative Risk Indicators & Possible Climate Change Trends in Hong Kong and Implications for the Slope Safety System”, *Geotechnical Engineering Office Report No. 128*.

15. Stanhill G. and J.D. Kalma, 1995, “Solar dimming and urban heating at Hong Kong”, *Int. J. Climatol.*, **15**, 933-941.

16. Leung Y.K., K.H. Yeung, E.W.L. Ginn and W.M. Leung, 2004, “Climate Change in Hong Kong”, *Hong Kong Observatory Technical Note No. 107*.

17. Li, X., and P. Zhai, 2000: On indices and indicators of ENSO episodes. *ACTA Meteoro. SINICA*, **58**, 102-109 (In Chinese with English Abstract)

Table 1. Raingauge Station and Grouping Information

Region	Station Name	Station Number	Station Attitude* (m)	Data Period
Urban	Hong Kong Observatory	1	30	1884-2005
	Tai Tam Tuk Reservoir	7	55	1947-2005
	Happy Valley Race Course	24	35	1953-2005
High Ground	Chuen Lung Country Park	52	330	1954-2005
	Tai Po Kau Country Parks	75	130	1958-2005
	Tate's Cairn	77	575	1959-2005
New Territories East	Sha Tau Kok	26	35	1950-2005[1]
	Sam Yuk Middle School	27	105	1953-2005[2]
	Sai Kung Farm	82	45	1961-2005[1]
New Territories West	Castle Peak Farm	31	10	1953-2005
	Tai Lung Farm	58	35	1955-2005
	Au Tau Pond Fish Farm	65	5	1961-2005
Offshore	Waglan	3	50	1947-2005[3]
	Cheung Chau	34	34	1953-2005[3]
	Shek Pik Reservoir	68	35	1958-2005

[1] Automatic raingauge data from 1984-2005

[2] Automatic raingauge data from 1985-2005

[3] Automatic raingauge data from 1992-2005

*above mean sea level

Table 2. Trend analysis of annual rainfall in the five regions of Hong Kong in the period between 1956 and 2005. Trends are in mm per decade. All trends are not statistically significant at the 5 % level.

Urban	High Ground	New Territories		Offshore	Average of all regions
		East	West		
+103	+76	+34	+57	+40	+65

Table 3. Trend analysis of the difference in annual rainfall between various regions and Offshore region. Trends are in mm per decade. Statistically significant trend (at 5% level) is shaded.

Urban	High Ground	New Territories		Average of all regions
		East	West	
+63	+37	-5	+17	+26

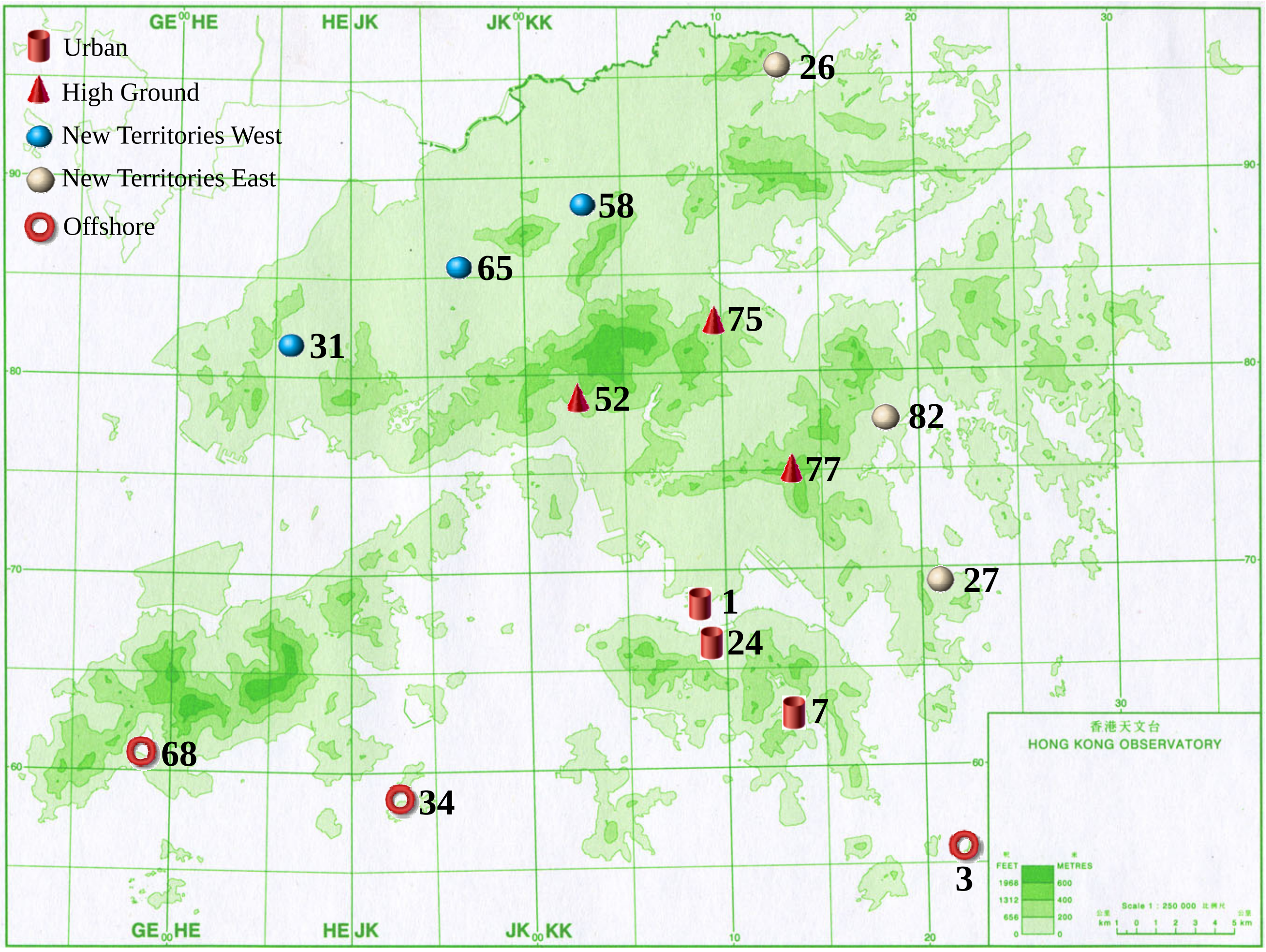

Figure 1. Locations of raingauge stations of the five regions

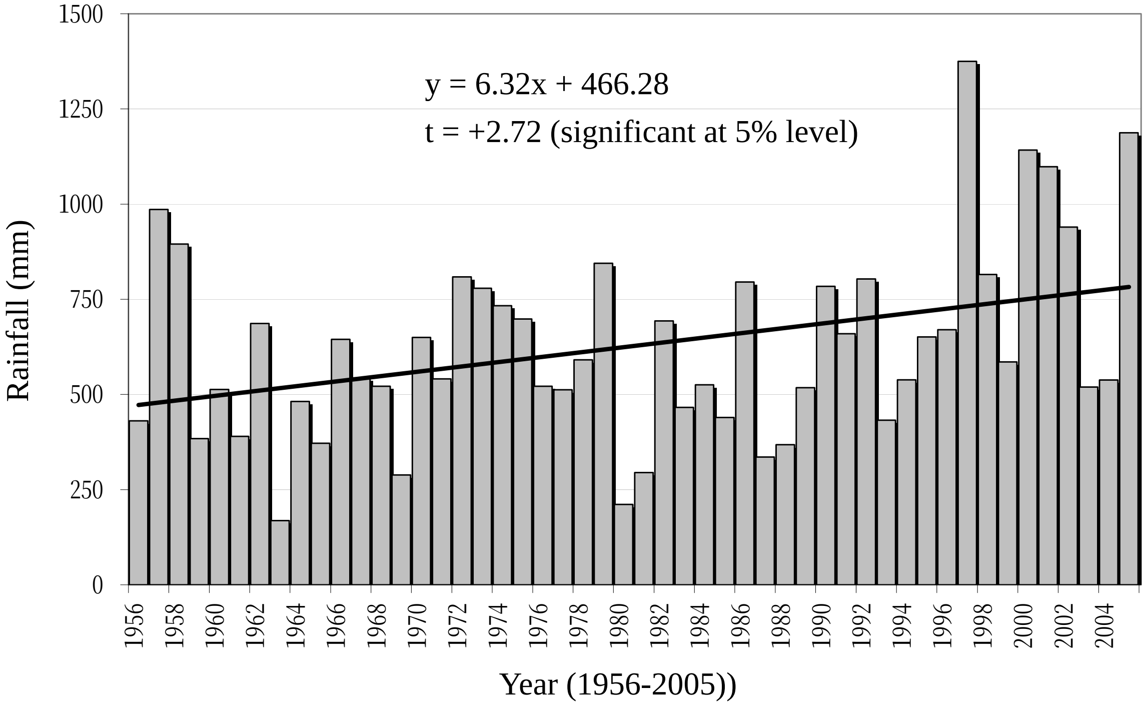

Figure 2. Time series showing the annual rainfall difference between the Urban region and Offshore region (Urban minus Offshore). The solid line indicates the linear trend over the period between 1956 and 2005.

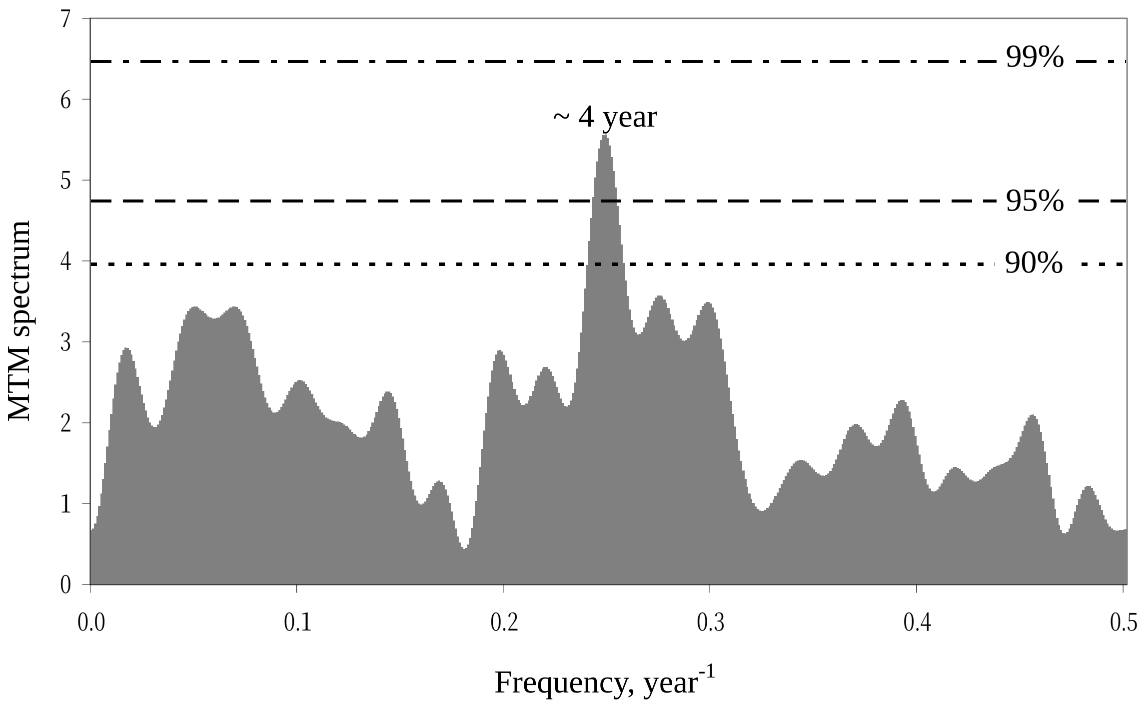

Figure 3. MTM spectrum of the average annual rainfall of all regions. The 90%, 95% and 99% confidence levels with respect to the white noise spectrum are shown by the dashed lines.

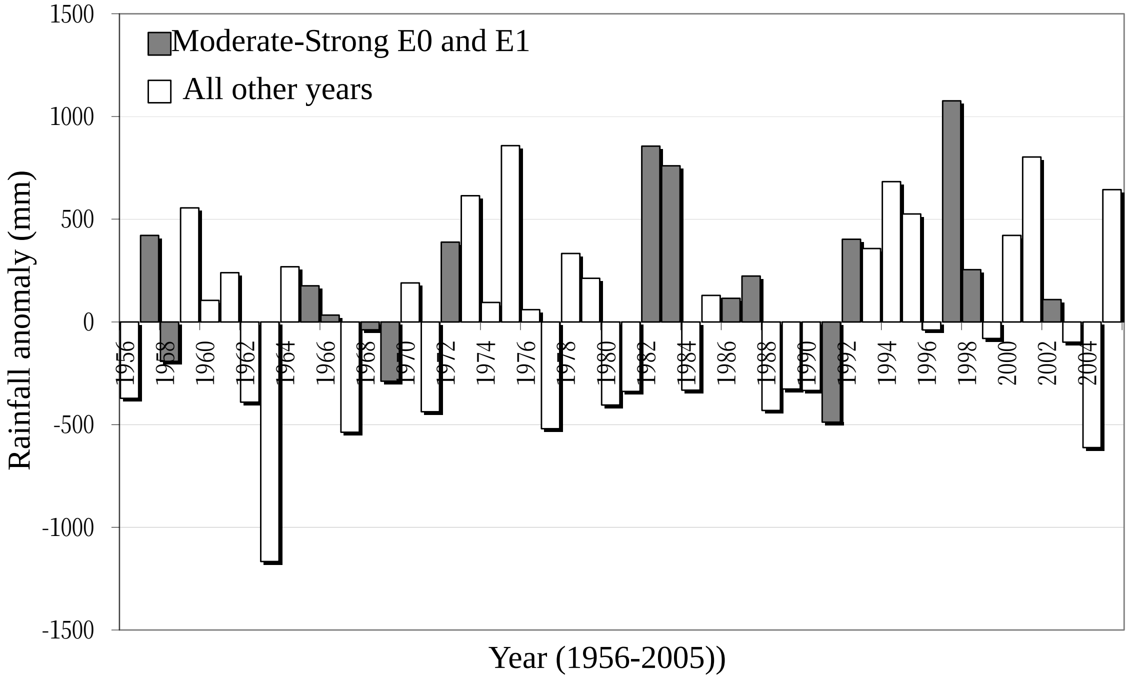

Figure 4. Annual rainfall anomaly for the average of all the five regions. Anomaly is with reference to 1961-1990 normal. Years of moderate to strong El Niño onset year (E0) and the year immediately following the El Niño onset year (E1) are 1957, 1958, 1965, 1966, 1968, 1969, 1972, 1982, 1983, 1991, 1992, 1997, 1998 and 2002. Classification of ENSO years are based on Li and Zhai (2000) [17].